Anatomy and imaging of the equine metacarpophalangeal/metatarsophalangeal joint

Anatomie en beeldvorming van het kogelgewricht bij het paard

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ABSTRACT

The metacarpo-/metatarsophalangeal joint is a high motion joint and is therefore prone to be injured. Lameness attributable to the metacarpo-/metatarsophalangeal joint is a frequent cause of early retirement from athletic activity in horses and should therefore be detected as early as possible. The basis of the examination for lameness remains the clinical examination, including a complete motion examination in which the lameness is unambiguously localized by means of local anesthesia. A combination of radiography and ultrasonography is often sufficient for visualizing the lesions.

However, in the absence of clear radiological or ultrasonographical findings, more advanced imaging modalities, such as computed tomography (CT) or magnetic resonance imaging (MRI), are necessary. The choice of technique largely depends on the tissue characteristics of the expected lesion, the cost restraints of the owner, and the willingness to take the risk of general anesthesia.

SAMENVATTING

Het kogelgewricht bij het paard is gevoelig voor kwetsuren omwille van de hoge belastingsgraad. Manken ter hoogte van dit gewricht is vaak de oorzaak van het vroegtijdig beëindigen van een sportcarrière. Daarom is het belangrijk eventuele problemen ter hoogte van de kogel zo vroeg mogelijk op te sporen..

De basis van het kreupelheidsonderzoek blijft het klinisch onderzoek inclusief een volledig bewegingsonderzoek waarbij door middel van lokale anesthesie de kreupelheid eenduidig gelokaliseerd wordt. Een combinatie van radiografie en echografie is vaak voldoende voor het visualiseren van letsels. Soms zijn er echter meer geavanceerde beeldvormingmodaliteiten nodig, zoals computed tomography (CT) of magnetic resonance imaging (MRI). De keuze tussen deze twee beeldvormingsmodaliteiten hangt voornamelijk af van het type letsel dat men verwacht, het verschil in kostprijs tussen de twee onderzoekstechnieken en de bereidheid om het paard onder algemene anesthesie te brengen.

INTRODUCTION

The metacarpophalangeal/metatarsophalangeal (MCP/ MTP) joint of the horse is a high motion joint sustaining high forces during acceleration and is therefore prone to injury (Pool and Meagher 1990). Lameness attributable to the MCP/ MTP joint is a frequent cause of early retirement from athletic career in horses and should therefore be detected as early as possible (Rossdale *et al.* 1985; Santschi 2008).

A systematic approach in the diagnosis of lameness of the MCP/MTP joint area is necessary and leads the veterinarian to a diagnosis in most cases. The traditio-

nal evaluation of the equine musculoskeletal system usually consists of a clinical examination including local analgesia and, if necessary, radiographs. However, horse owners become more knowledgeable and demand better care with a more accurate diagnosis and prognosis. Therefore, if a detailed diagnosis cannot be obtained using this methodology, more advanced techniques, such as ultrasonography (US), nuclear scintigraphy, computed tomography, magnetic resonance imaging or diagnostic arthroscopy may be indicated (Martinelli *et al.* 1996).

The goal of the present article is to present the main anatomical features of the equine MCP/MTP

joint and to review the different imaging modalities available for MCP/MTP joint evaluation. The technical specifications of each technique and their diagnostic value for the different pathologies encountered at the level of the MCP/MTP joint are discussed.

ANATOMY

The MCP/MTP joint comprises four bones: the third metacarpal (MCIII) or third metatarsal (MTIII) bone, the proximal phalanx (P1) and the paired proximal sesamoid bones. The distal epiphysis of the MCIII or MTIII has two convex condyles and a sagittal ridge that separates them. This distal epiphysis articulates with P1 distally and with the sesamoid bones palmarly/plantarly (Barone 1986).

An articular capsule and multiple ligaments reinforce the MCP/MTP joint. The ligaments can be divided into three main groups: the palmar (intersesamoidean) ligament, the sesamoido-phalangeal ligaments and the metacarpo-/metatarsophalangeal ligaments. The metacarpo-/metatarsophalangeal ligaments are subdivided into the collateral ligaments, the dorsal reinforcement of the articular capsule and the suspensory ligament. Each collateral ligament has a superficial and a deep part. The dorsal fibrous reinforcement of the articular capsule has fibres running in different directions. At the lateral and medial aspect of the MCP/MTP joint it fuses with the respective collateral ligament. The lateral and medial branch of the suspensory ligament inserts at the apical and abaxial border of the proximal sesamoid bones. At the level of their attachment, they form a small "extensor" tendon that runs in a dorsodistal direction and fuses dorsally with the common (front limb) or long (hind limb) extensor tendon at the level of P1 (Barone 1989; Vanderperren et al. 2008; Weaver et al. 1992).

The articular capsule is formed by an outer stratum fibrosum, strengthened by the above-mentioned ligaments, and an inner stratum synoviale, responsible for the homeostasis of the synovial fluid. The MCP/MTP joint has a smaller dorsal recess and a larger palmar recess. In the dorsoproximal recess of the MCP/MTP joint, the synovium and fibrous connective tissue forms a fold (plica), projecting distally from the dorsoproximal attachment of the joint capsule and tapering to a thin edge. This covers the transition zone between the condylar cartilage and the attachment of the joint capsule (Dabareiner et al. 1996).

RADIOLOGY

Over the past decade, digital radiography has largely replaced conventional radiography. Digital radiography represents on the one hand a higher investment cost than an analogue system, but on the other hand, it has several distinct advantages: less film waste, lesser films per examination due to the extra possibilities for image post-processing and improvement of the image quality due to the almost instantaneous acquisition time (images can be reviewed on site). For the correct interpretation of digital radiographs, recognition of the specific artefacts associated with digital radiography is required (Dalla Palma 2000; Jimenez et al. 2008; Mattoon 2006; McKnight 2004; Pilsworth and Head 2010).

A standard radiographic examination of the MCP/MTP joint comprises four projections (LM, D45L-Pa/PlMO, D45M-Pa/PlMO, DPa/Pl) (Figure 1) (Richard and Alexander 2007). The LM projection is performed with the horse weight-bearing and a horizontal x-ray beam parallel to the heel bulbs (Edwards 1984). The condyles of the MCIII or MTIII bone and sesamoid bones should be superimposed on each other and the MCP/MTP joint space should be identifiable (Park 2000). The standard oblique projections are made with the primary beam orientated at an angle of 45° (medial or lateral) to the sagittal plane. This angle can be adapted depending on the lesion identified or suspected on the initial LM projection (Edwards 1984). The dorso-medial/-lateral aspect of P1 and the borders of the proximal sesamoid bones, superimposed on the distal aspect of the MCIII or MTIII bone, should be identifiable on the oblique projections. Superimposition of the base of the sesamoid bones over the proximal palmar/plantar process of the P1 should be avoided (Park 2000). The DPa/DPl projection is performed with a horizontal x-ray beam, centered on the joint. The superimposition of the proximal sesamoid bones over the joint space can be avoided by angling the x-ray
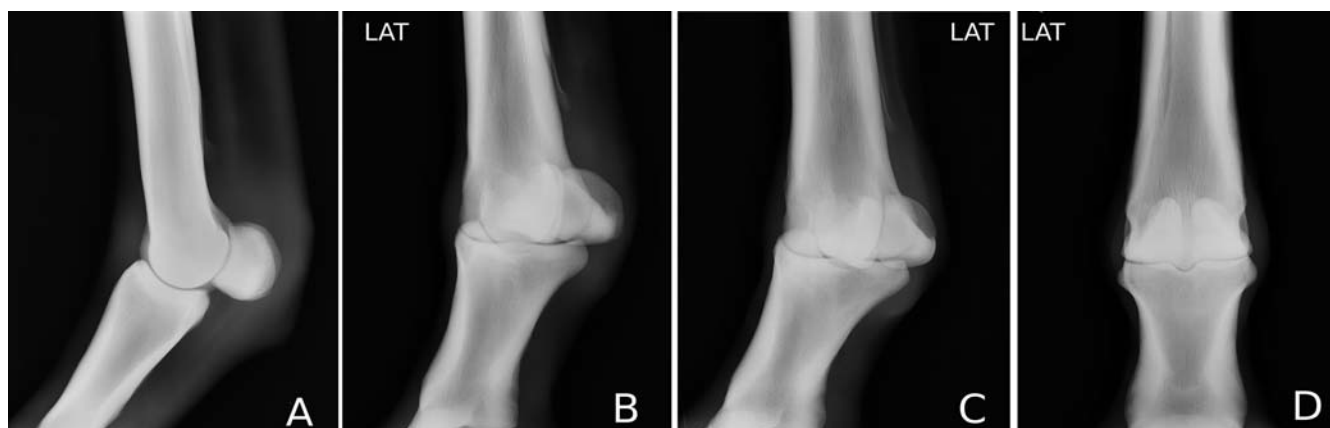

Figure 1. The normal radiographic appearance of the metacarpo-/metatarsophalangeal joint. A. conventional LM projection, B. D45L-Pa/PlMO projection, C. D45M-Pa/PlMO projection, D. DPa/Pl projection.
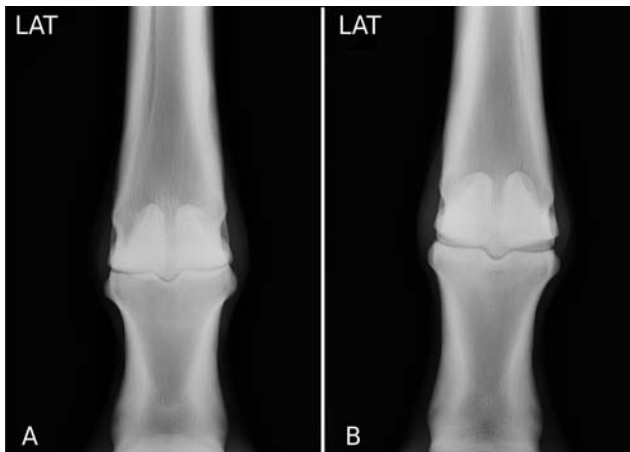
Figure 2. Illustration of the contrast in visualization of the joint space between A. normal DPa/Pl projection and B. angled DPr/Pa(Pl)DiO projection, by avoiding the superimposition of the proximal sesamoid bones onto the joint space.

beam proximodistally (approximately 10° for the DPa projection; 15° for the DPl projection) (Figure 2) (Butler *et al.* 2000). Additional projections, like a flexed LM or D125°Di-PaPrO or flexed D35°Di-PaPrO or flexed DPr-DDiO (Figure 3), can be obtained to highlight specific areas of the joint, respectively the distal aspect of the sagittal ridge (flexed LM) and palmar (DDi-PaPrO), central (D35°Di-PaPrO), dorsodistal (DPr-DDiO) articular surface of the MCIII or MTIII bone (Richard and Alexander 2007). The decision on which additional projection is the most suitable depends on the pathology suspected in the individual case. However, these projections are technically challenging and represent an additional exposure risk. Therefore, more advanced imaging techniques can be used to evaluate the above-mentioned regions, thus obliterating the extra radiation hazard for the practitioner (Denoix *et al.* 1996; McDiarmid 1995).

On normal LM radiographs, the joint surface of the distal MCIII or MTIII bone describes a smooth curve, with a mild flattening in its palmarodistal aspect. In some horses, the distal metaphysis of the MCIII or MTIII bone shows some irregularity at the level of the fused physis. A mild remodeling (osteophytosis and/or enthesiophytosis) of the dorsoproximal aspect of P1 is a common finding in older horses, but can also be an early sign of degenerative joint disease. On a DPa/DPl projection, the joint should be approximately symmetrical, with the medial condyle being slightly wider than the lateral. A clear demarcation between the subchondral bone plate of P1 and the underlying cancellous bone should be present. On the oblique projections, the sesamoid bones have a smooth outline of their palmar/plantar aspect. Their axial and abaxial surfaces may show some unevenness due to the insertion of ligaments. However, a marked roughening at that level is abnormal (Butler *et al.* 2000).

In Thoroughbred and Warmblood horses, several radiographic variations are seen at the level of the MCP/MTP joint (Hauspie *et al.* 2010; Kane *et al.* 2003b). Some variations, like flattening of the sagittal ridge, vascular channels in the proximal sesamoid bones in the MCP/MTP joint have no influence on the performance of Thoroughbred horses. Other changes, like palmar supracondylar lysis, enthesophyte formation on the fore proximal sesamoid bones and proximal dorsal fragmentation of P1 in the hind MTP joint and enthesophyte formation on the hind proximal sesamoid bones, are associated with reduced performance in Thoroughbred horses (Kane *et al.* 2003a). However, the influence of these variations on the performance of Warmblood horses is not known.

ULTRASONOGRAPHY

Ultrasonography is a useful imaging modality for the examination of joint abnormalities as it enables the evaluation of soft tissue components of the joint and provides information on the regularity of the bony contours (Redding 2001; Smith 2008).

For optimal ultrasonographic examination, the joint should be clipped, cleaned and coated with conducting gel. Only in fine haired horses, it is possible to perform the examination without clipping. If the owner is unwilling to allow the horse to be clipped, it is better not to perform the examination (Mitchell 2009; Redding 2001).

Figure 3. Illustration of additional projections, highlighting the different regions of the metacarpal condyle. A. flexed LM; B. DDi-PaPrO-125; C. flexed D35°Di-PaPrO; D. flexed DPr-DDiO

The MCP/MTP joint can be examined with a high frequency (7.5-10 Mhz) linear transducer. Sometimes the use of a standoff pad is needed. The MCP/MTP joint can be approached from all aspects. With the dorsal approach, the joint capsule, proximal synovial fold, the dorsoproximal aspect of the P1 and cartilage of the dorsal aspect of the distal MCIII or MTIII condyles can easily be imaged. With a lateral and medial approach, the collateral ligaments are imaged. Using a palmar/plantar approach, the attachment of the branches of the suspensory ligament can easily be identified, although the assessment of the palmar ligaments and the palmar/plantar aspects of the distal metacarpal/metatarsal condyles are limited to a small window between the proximal sesamoid bones and the palmar/plantar aspects of the distal MCIII or MTIII bone (Busoni 2001; Denoix *et al.* 1996; Smith and Smith 2008; Smith 2008).

Dynamic ultrasonographic examination of the MCP/MTP joint allows a better evaluation of the joint capsule by eliminating hypoechogenic relaxation artefacts. Flexion and extension can also be helpful in demonstrating the mobility of an osteochondral fragment and in evaluating fluid movement (Denoix 1996; Modransky *et al.* 1983; Redding 2001; Reef 1998; Vanderperren *et al.* 2009b). The comparison of the same structure with the contralateral limb improves the sensitivity and specificity of the ultrasonographic diagnosis (Denoix and Audigie 2001; Redding 2001). A large obstacle is how to interpret the information and how to avoid artefacts created during an ultrasound examination (Redding 2001; Whitcomb 2009).

Ultrasound is used to complement the radiographic examination as it allows an earlier detection of degenerative changes, like thickening of the joint capsule, thinning of the joint cartilage, new bone formation at the articular margins, at the level of the MCP/MTP joint. With US, these changes can be demonstrated as early as twenty days after the onset of a trauma, whereas with radiography, they can only be demonstrated at day forty (Rasera *et al.* 2007).

At the dorsal aspect of the MCP/MTP joint, the subchondral bone should be smooth and the thickness of the proximal synovial fold should be less than 5mm. The cartilage should have a smooth appearance. The collateral ligaments have a parallel fibre pattern and a uniform echogenicity and should be comparable in thickness. In the medial and lateral palmar/plantar pouches of the joint a small amount of anechoic fluid containing a small amount of echoic strands, representing synovial villi, can be detected in a normal horse. The branches of the suspensory ligament are located just palmar/plantar to these pouches. They have a parallel fibre pattern and uniform echogenicity (Smith and Smith 2008). In an experimental setup, it has been shown that ultrasound is accurate and reliable for the detection of cartilage defects (Disler *et al.* 2000). However, in the clinical setting, it is often difficult to obtain diagnostic images and only a limited part of the condylar cartilage can be visualized.

SCINTIGRAPHY

Scintigraphy is sensitive to the detection of increased bone turnover and allows to detect lesions before they are radiographically evident (Chambers *et al.* 1995).

The examination is started with an intravenous injection of a radiopharmaceutical (a bone-seeking polyphosphonate, labelled with the radioactive compound technetium-99m). This polyphosphonate binds to any exposed hydroxyapatite crystal surface (areas with active bone remodeling or dystrophic mineralization). The vascular phase (or phase I) images are acquired immediately after the injection and highlight the radiopharmaceutical as it courses through the blood vessels. Pool-phase (or phase II) images are acquired within fifteen to twenty minutes after injection, while most of the radiopharmaceutical is in the soft tissues. Bonephase (or phase III) images are acquired two hours after injection to allow the radiopharmaceutical to bind to the bone and clear from the soft tissues (Chambers *et al.* 1995).

It is important to realize that an area of increased radiopharmaceutical uptake, reflecting an area with increased blood flow or osteoblastic activity, does not necessarily reflect bone pathology. A standard pattern of radiopharmaceutical uptake in the MCP/MTP joint has been established in non-lame horses and significant differences are present compared to lame horses (Biggi *et al.* 2009).

Scintigraphy is a highly sensitive method for localizing the region responsible for the lameness, but because of the low specificity, the result must always be interpreted together with the result of the clinical examination and other imaging modalities in order to avoid misinterpretation (Weekes *et al.* 2004).

COMPUTED TOMOGRAPHY

Compared to radiography and ultrasonography, computer tomography provides a highly detailed cross-sectional image and the possibility of three-dimensional imaging obtained by reconstruction without the problem of superimposition of the bony structures (van Weeren and Firth 2008; Vanderperren *et al.* 2008). The main disadvantage of CT compared to the conventional equipment is the need for general anesthesia. CT is ideally suited for the cross-sectional analysis of anatomic features and provides an excellent detail of osseous structures. In addition, osteolysis and osteogenesis can be detected well before any changes can be perceived on conventional radiographs and before these changes become clinically significant (Schramme *et al.* 2007; Young *et al.* 2007). Besides bones, CT can also be used to evaluate soft tissues. Although the quality of the soft tissues is steadily increasing, soft tissue contrast is still inferior to MRI (Bienert and Stadler 2006; Vanderperren *et al.* 2008). The use of contrast enhanced CT, with regional perfusion of contrast agent, can enhance the identification of lesions in the soft tissues (Puchalski *et al.* 2007). The cartilage can be eva-
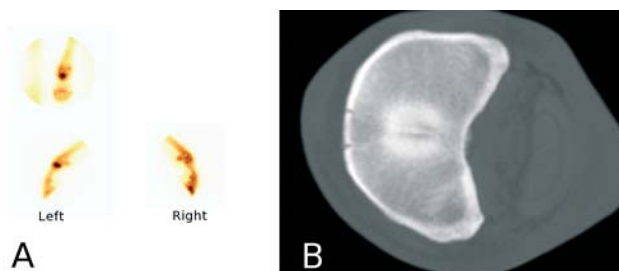
Figure 4. A. Image illustrating the increased uptake on scintigraphy in the proximal aspect of the proximal phalanx of the left hind metatarsophalangeal joint compared to the contralateral limbs. The accompanying CT image (B) illustrates an incomplete sagittal fracture of the first phalanx.

luated with the use of a contrast arthrogram (Vander-perren *et al.* 2008)

In the MCP/MTP joint, CT can identify subchondral bone sclerosis without abnormalities on radiography and it can detect a subchondral cystic lesion or fissure before it becomes radiographically visible (Figure 4). This can help in the early diagnosis of subtle joint lesions prior to the development of gross joint lesions (Hanson *et al.* 1996; Kawcak *et al.* 2000; Morgan *et al.* 2006).

MAGNETIC RESONANCE IMAGING

With MRI, an image is obtained based on the magnetic properties of the tissue. The magnetic field strength is measured in Tesla (T). In equine medicine, several systems are used, ranging from low field (0,2T) to high field (1,5T). The high field systems enable faster scanning times and have a better image quality (Tucker and Sande 2001). Both low-field and high-field MRI give comparable data about abnormal structures, although lesions are more detailed with a high field MRI. A high field system is superior in the detection of articular surface abnormalities. (Murray *et al.* 2009). MRI enables the detection of small and subtle lesions without the presence of gross structural changes (Kraft and Gavin 2001).

A standing low field MRI system has been developed for horses to avoid the risk of general anesthesia, to ease patient handling and to reduce the operating costs. Its purchase and maintenance are considerably cheaper, but it provides a poorer magnetic field homogeneity, which can result in image degradation and artefacts. Due to the lower magnetic field used in the standing MRI system, longer imaging times are necessary. This increases the risk of movement of the horse and thus the use of motion correction software is necessary (Mair *et al.* 2005; Murray and Mair 2005; Tucker and Sande 2001).

The high soft tissue contrast afforded by MRI makes this modality particularly suited for the evaluation of lesions that were suspected on clinical and radiological examinations, but that could not be clearly identified (Schramme *et al.* 2007; Widmer *et al.* 1999). The main advantage of MRI over radiography and diag-

nostic ultrasound is that it provides both anatomical and physiological information in multiple planes. Most of the soft tissues surrounding the MCP/MTP joint can readily be identified even with a low field system (Martinelli *et al.* 1997). The advantage of MRI over CT is that MRI does not use ionizing radiation and can simultaneously image bone and soft tissues with a better soft tissue contrast than CT (Mair *et al.* 2005).

As with ultrasound, the interpretation of a MRI examination requires the knowledge of the normal anatomy and characteristic findings in abnormal tissues (Chaffin *et al.* 1997).

In the equine MCP/MTP joint, MRI has illustrated lesions at the level of the flexor tendons, sesamoidean ligaments and subchondral bone pathology, with or without an associated cartilage pathology, in the absence of radiographic or ultrasonographic abnormalities (Dyson and Murray 2007; Sampson *et al.* 2007) (Figures 5 and 6).

Figure 5. Conventional radiograph (A) and corresponding MRI images (B and C) illustrating a subchondral cyst in the proximal aspect of the proximal phalanx. This lesion can be suspected on the initial radiographs but is better visualized on the MRI images.
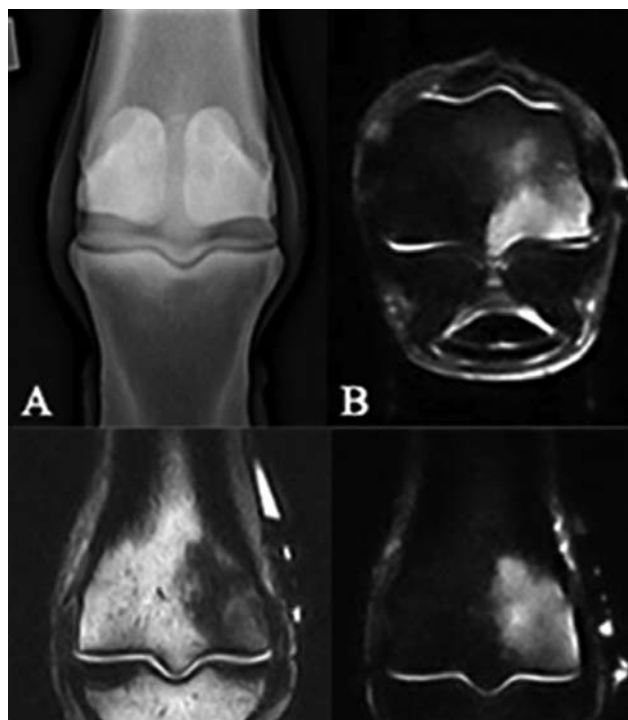

Figure 6. Illustration of a subchondral bone lesion at the level of the medial metacarpal condyle. The conventional radiograph (A) shows no abnormalities while there is a clear visualization of the bone oedema on the corresponding MRI images (B, C, D).

ARTHROSCOPY

Arthroscopy permits a direct visualization of the synovial membrane and articular cartilage of the MCP/MTP joint (Figure 7) (McIlwraith *et al.* 2005). Arthroscopy however, does not allow visualization of the entire articular surface of P1 and condyles of the MCIII or MTIII bone. The cartilage of the condyles of the MCIII or MTIII bone can be visualized almost completely, with exception of a limited part at the palmaro/plantarodistal aspects. (Vanderperren *et al.* 2009a). In contrast, only the dorsal articular margin of P1 can be visualized. However, it has been shown that in joints with mild cartilage damage, the status of the cartilage on the visible margin of P1 has a good correlation with the status of the entire articular surface of P1 (Brommer *et al.* 2004). Arthroscopy is considered the most valid method for cartilage evaluation, but in case of small cartilage lesions there is a risk of overestimation of the defect size. The advantage of arthroscopy compared to the other diagnostic modalities is the possibility of immediate treatment of the iden-

tified joint problem (Niemeyer *et al.* 2011; Spahn *et al.* 2011).

CONCLUSIONS

A thorough and comprehensive clinical examination remains the basis for the evaluation of athletic problems. Based on the examination, lameness can be further localized by the use of local analgesia or the lesions can be visualized by means of different imaging modalities.

Radiography is the standard imaging modality for the visualization of the MCP/MTP joint. However, it has its limitations because radiographs provide a two-dimensional representation of a three-dimensional object and have a bad soft tissue contrast. Ultrasound is often used in addition to radiography to avoid this superposition of the different structures. Unfortunately, some structures are difficult to evaluate because of their location (Kraft and Gavin 2001). Radiography and ultrasonography are usually sufficient for the diagnosis of synovitis, capsulits and osteoarthrosis of the
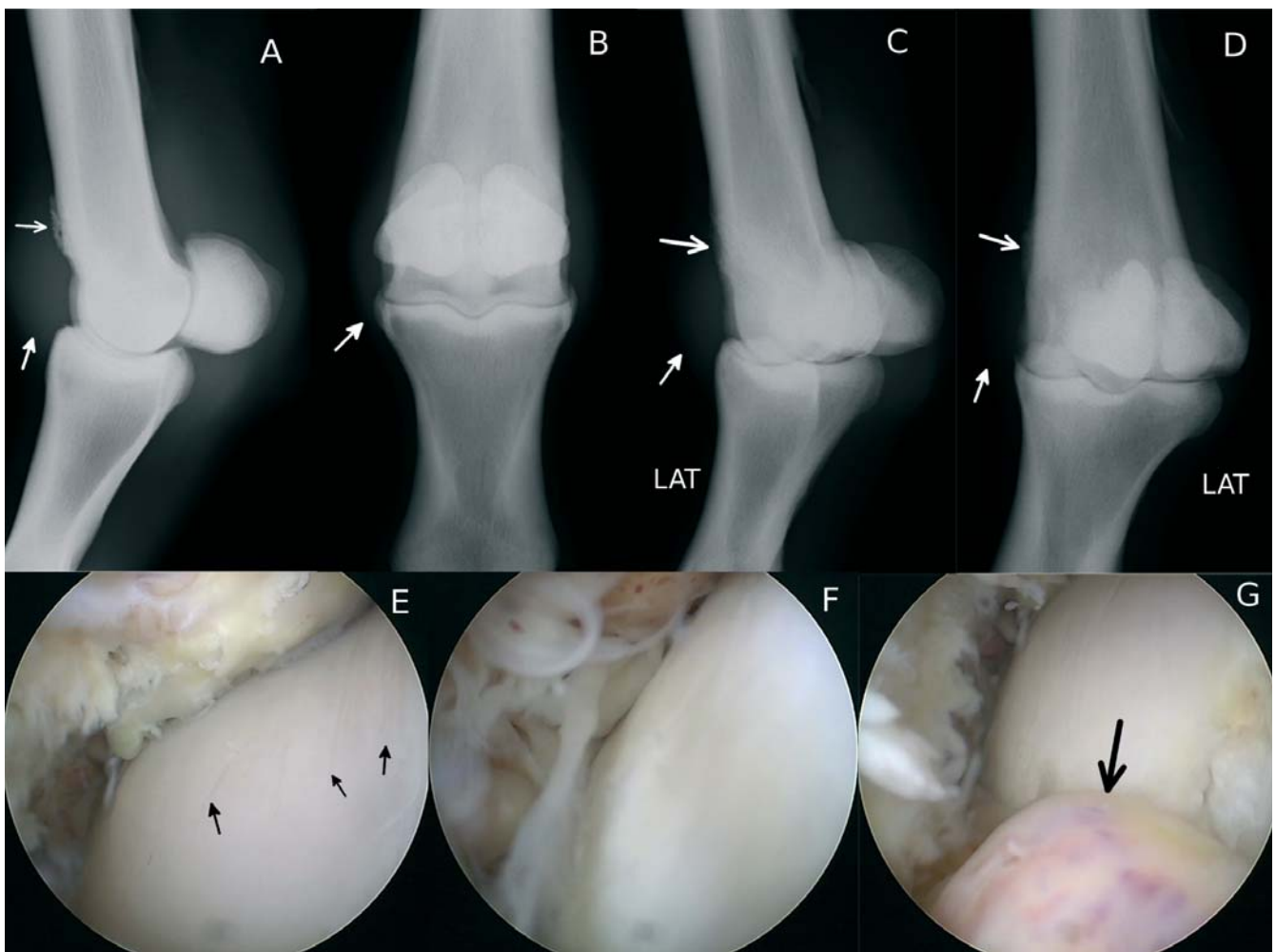

Figure 7. Conventional radiographs (A, B, C, D) and corresponding arthroscopy images of the dorsal pouch of the metacarpophalangeal joint (E, F, G). The radiographs (A, B, C, D) only demonstrate a large soft tissue swelling at the level of the metacarpophalangeal joint (white filled arrowhead), and irregular outlined new bone formation at the dorsodistal aspect of the MCIII bone (white open arrowhead). The diagnostic arthroscopy revealed some superficial cartilage erosions at the dorsal metacarpal condyle (medail shown in (E), a large amount of synovial proliferation (F) and a hypertrofic proximal synovial fold (medail shown in (G)).

MCP/MTP joint. However, if clinical signs of a MCP/MTP joint problem are present without detectable radiographic or ultrasonographic abnormalities, more advanced imaging techniques, like computed tomography, magnetic resonance imaging or arthroscopy, should be considered (Sampson *et al.* 2009; Young *et al.* 2007; Zubrod *et al.* 2004). They can be useful in the early diagnosis of subchondral bone pathology, microfissures, complex periarticular soft tissue pathology or cartilage damage.

Nevertheless, the choice of technique(s) depends on the tissue characteristics of the expected lesion, the financial constraints of the owner, the availability of the different modalities and the willingness of the owner to take the risk of a general anesthesia if required (Kraft and Gavin 2001).

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